

THE
METHOD OF COLLECTING FLUE-DUST

AT
MEETINGS ON THE LAHN.

BY
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*THE METHOD OF COLLECTING FLUE-DUST AT EMS ON
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BY T. EGLESTON, PH.D., NEW YORK CITY.

(Read at the Boston Meeting, February, 1883.)

THE importance of condensing the gases which escape from furnaces so as to save both the fine particles of ore carried off mechanically and those which are volatilized, has for a long time occupied the serious attention of metallurgists in all parts of the world. It was my good fortune during the last summer to visit the lead and silver works at Ems, near Coblenz on the Rhine, and through the politeness of Mr. Freudenberg, General Director of the works, to study in detail their methods of condensation, and to receive from him the important results which have been obtained through a series of experiments lasting over a number of years. I have thought that these results would be of great interest to the members of the Institute and to other metallurgists in the United States, and I have, therefore, with the assistance of Mr. Freudenberg, prepared a careful, detailed description of the construction of the flues, as well as an account of the various experiments which have been made with them, and the conclusions arrived at as the result of these experiments.

It may be said, in general, that the reason why so little attention has been paid in the metallurgical works of the United States to the collection of flue-dust, is that we are not generally aware of the large amount of material carried off by the gases. This is owing partly to the fact that little or no attention is paid to the subject, and also to the fact that the assays, which are almost invariably made in the dry way, show a result so much below the real contents of the ore that the loss appears smaller than it really is. If assays were always made in the wet way the result would be quite different,

and probably we would have long ago given attention to this subject of flue-dust.

All the experiments that have been made in the direction of saving the materials carried off by the gas may be comprised in two categories,—those in which attempts have been made to collect the dust by means of water, and those in which water has not been used. The condensation of gases by means of water is at best a very rude method. Experience has shown that both solid and gaseous products, even when not under the influence of pressure or of high velocities, may traverse considerable depths of water without change and with almost no condensation. Water condensation has been used in this country to some extent, but its results have always been unsatisfactory, both because the material which is so condensed is very difficult to treat, being collected as a liquid mud, which when dry is in the form of an impalpable powder, and because the water supply in most of the places where the works are situated is very limited; so that at the present time most of the serious experiments that are being made are conducted altogether without water. It becomes at once a matter of the first importance in these experiments to know whether great length or great volume of flue within a given extent, or great surface in a limited volume, is better for this purpose of condensing the gases. The experiments made at Ems are quite conclusive in regard to this question, and show that great surface is the most indispensable requisite.

It will generally be found that three things are required in any method of condensation. The first, and what is generally considered the most important of these, is the settling and complete separation of the fine particles of ore carried off mechanically by the draft. The second, which in all works where the precious metals are treated is much more important, is the condensation of the material which is volatilized or carried off in a gaseous condition. The third is the retaining of all the particles once at rest in the position where they have first fallen in such a way that they may afterwards be collected without loss of the precious metals or danger to the health of the workmen. To the latter condition but little attention has been paid in this country. I have formerly had occasion to refer to a very ingenious method adopted by the Pennsylvania Lead Works,* for holding the precipitated or condensed material in the

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position where it fell, which, so far as I know, is the only experiment of this kind made in this country. The question of choice between very long flues and very wide chambers seems to be settled definitely, as we shall see by the experiments made in the works at Ems, the conclusion being general that a maximum of surface, without special reference to volume or length, is what is required, and that this maximum of surface can be better gained, so far as the condensation is concerned, and also more economically arrived at as to cost, by the arrangement which is there used.

The experiments made for condensing the materials contained in the gases were commenced in a systematic way in the year 1874, when, with the object of obtaining volume, both systems, that of short wide chambers, and that of long narrow flues, were constructed, in order to ascertain what should be the principle adopted in the future construction of the works. In order to understand the experiments thoroughly, a ground plan of the smelting works, and of the flues, and a profile of the flue from its point of starting in the works to where it finally terminates in the chimney which discharges the gases into the air, are given on Plate I.

The Ems Lead and Silver Works are composed of two separate establishments. The one which is nearest to the famous watering-place is the mechanical preparation or ore-dressing works, which is one of the largest, the most complete, and also one of the best known in Europe, but with which we have nothing to do in this article. The mines, the smelting works, and a small part of the mechanical preparation works are situated about four miles distant in a valley running at right angles to the valley of the Lahn, through which a small stream runs. The mine and part of the crushing and selecting works are situated on the eastern side of this stream; the smelting works are situated on the west bank of the same stream. These latter consist of a series of buildings containing the furnaces and storehouses, built upon a plateau several meters above the stream, at the foot of a high hill which next the works is very steep, but which, after passing Station 22 (Plate I.), rises more gently. Leading away from the works up the hill, are a series of flues of various sizes, the first part of which runs along an old road up to the first chimney at Station 22, and from there goes directly over the hill to the highest chimney at Station 47. The U-shaped part of the flue *c, d, e, f, g, h*, on which the shaft and roasting furnaces are situated, is joined to the furnaces by means of short flues. The plan shows the

position and arrangement of all of these buildings and flues. The construction details of the flues at different points will be given later.

The main flue is 1700 meters in length; counting all its branches, its total length is 2271.48 meters. The greatest section of the flue is 4.512 square meters. Its total wall surface is 18.060 square meters. Its highest point at Station 47 is 178 meters above the floor of the furnaces. At this highest point it enters a chimney whose section at the bottom is 2.47 meters and at the top 1.80 meters, and whose height is 45 meters, its top being 223 meters above the furnaces. The ventilating flue N, and its chimney L, which were formerly used for ventilating the shaft and cupel furnace house G, and the flue from the roasting stables, which ends in the chimney at Station 22, have no connection with the main flue. The short and steep flue *a b*, with its arm *c d*, connects the shaft and cupel furnace house, and also some of the roasting furnaces, with the condensing chamber at Station 16. The gases enter on the southerly side, in the compartment I, Fig. 10, Plate II. These gases move towards the northerly side; those in compartment II towards the southerly side. The flue *e f'*, *f g*, *h i*, *K*, connects the other roasting furnaces with the main flue also at Station 16, but follows around an old road going gradually and with an irregular curve up the hill, and empties its gases into the compartment III of the condensing chamber at *i*, Station 16. The gases enter on the northerly side in the compartment III, join those in compartment II, and enter the main flue at Station 15.

In order to make the description of the process quite clear, sections of the flues at different parts of its course have been given, both to show their methods of construction and the means used for obtaining both volume and surface.

Fig. 1, Plate II, is the flue leading from shaft furnace No. 2 to its union with that leading from No. 3, and from the point where the flues of Nos. 2 and 3 join, to the main flue; and also the flue leading from shaft furnace No. 4 to its union with the flue leading from shaft furnace No. 3.

Fig. 2 is the flue leading from shaft furnace No. 3 to the union of the flue with that from shaft furnace No. 2.

Fig. 3 is the flue from shaft furnace No. 1 to the main flue.

Fig. 4 is the flue from shaft furnace No. 5 to the main flue.

Fig. 5 is the flue from the point of union of the shaft furnace flues to the condensing chamber at Station 16.

Fig. 6 is the flue from the six most southerly roasting furnaces to the main flue, and also the flue from the dressed-ore storehouse to the two most northerly double roasting furnaces.

Fig. 7 is the flue from the two most northerly double roasting furnaces to the end of the dressed-ore storehouse; also the flue which runs by the most northerly roasting furnaces.

Fig. 8 is the flue of the most northerly roasting furnaces.

Fig. 9 is the flat flue of the most northerly roasting furnaces.

Fig. 10 is the first condensing chamber on the top of the first incline at Station 16.

Fig. 11 is the flue from the condensing chamber to the outside of the old chimney at Station 22, and from here to the edge of the woods, and from the edge of the woods to the flues connecting with the chimney at Station 47 on the top of the hill; also the flues connecting with the chimney.

Fig. 12 is the condensing chambers X and Y beyond the chimney, but connecting with it.

The flues in the interior of the shaft furnace building are made of sheet iron-plates $1\frac{1}{2}$ millimeters thick, and are hung 30 centimeters above the throat of the furnace. Figs. 1, 2, 3,* show some of the flues which lead from the cupel furnaces. The same kind of flues are used in the desilverization works, but they belong to their own system of condensation, and do not connect with the main flue. Some slight changes in these dimensions are occasionally made on account of local circumstances, but the size of the larger part of them is one square meter. The lower part of Figs. 1 and 2 have triangular projections, which have a base of two meters and are one meter high. All these pointed chambers have doors at the end of each incline, so as to make it possible to clean each pocket while the furnaces are in work. In order that the dust may not inconvenience the workmen while they are being cleaned, a sheet-iron-pipe 40 centimeters in diameter is put underneath them. Into this pipe another one which is conical at its upper end, fits loosely so that it can be moved up and down. This is put under the triangular pocket, the cone shoved up under it, the door opened, and the dust allowed to fall down into a receptacle made for the purpose, without interfering with the workmen. Iron flues connect with these pocket flues and conduct the gases to the main flue outside the building. By this very ingenious contrivance the dust can be almost automatically removed from the

* The exact location and position of each one of the figures is given in Table I., p. 10.

flues, the cleaning of which would be more or less difficult or dangerous, without stopping the furnace, and a large amount of valuable material is taken at short intervals out of the gases before they pass into the main flue, where they would otherwise be obliged to lie until the end of the campaign.

The flues on the outside of the shaft furnace building are of mason work. They have different sections according to the quantity of gas which they are required to carry off. These are shown on Figs. 4 to 9 and on Fig. 11. It has been found by experience that the arched flues, which at first characterized the whole of the construction, although of an excellent shape for resisting pressure from the outside, do not stand well against internal pressure, and that cracks are made in them so frequently that they are now being abandoned. The flue with rectangular section, Fig. 9, is not subject to these objections, and this style of construction is now adopted in these works and elsewhere in Europe. The roof of this flue is made of old rails covered with brickwork, and is inclined on the outside to one side, so as to shed the water. The cost of construction of this kind of flue is much less than when it is vaulted and it has a much greater volume for the same height and superficial area, and while it is just as likely to be acted on by the gases it is much more easily repaired. As it is much lower, the dust falling from the top falls from a less height, and is not therefore so likely to be carried any great distance from where it fell. The cross section of the condensing chamber at Station 16 is shown at Fig. 10. The ceiling of this chamber is made out of old rails with cap bricks. Above this is a wooden roof made tight with pasteboard underneath the tiles. In every section of the flue, at convenient distances, man-holes are made for cleaning it out, and to facilitate repairs. These man-holes were formerly about 0.6 meter in diameter, and were made exclusively on the top. It has been found more convenient to make large rectangular openings on the sides which, during the working, are closed with a wall of thin brick, and made tight on the sides and face with mortar. These walls are easily torn down to allow of the men entering on the floor of the flue with wheelbarrows to clean the dust out, and greatly facilitate the repairs to the flues. The earth is now being removed from the sides where the construction makes it possible, for the purpose of making these inlets. This has been found also to reduce the temperature of the flue, a matter of considerable importance so far as repairs to the flue are concerned, for, especially

with the arched flue, when the temperature is either high or very variable the walls have cracked and required constant repairs, which has at times necessitated the stoppage of the works. Every care is taken to carry the drainage of the surface over the top of the flue and not to allow the collection of water at any point. The flues over this whole line are now generally very tight. As the earth which covers or is in contact with them is much warmer than that of the neighboring ground, the grass is much greener than at other points, a sufficient evidence that no large amount of leakage occurs. I walked over the whole length of the flue, examining its construction carefully, and was conscious of the escape of the gases only in one or two points, and that to no very great extent, and principally in the arched portions of it. Repairs to such a flue could not generally be made without shutting down the works. In one of the works in Belgium I saw a very ingenious device for repairing a damaged flue without stopping the works. It consisted of a pipe of sheet-iron of the same section as the main flue, washed on the inside with a mixture of silicate of soda and sulphate of baryta. The part of the flue to be repaired was cut out, and this pipe substituted for it, while the permanent flue was being rebuilt. This iron pipe was about one meter in diameter, of thin sheet-iron, and had resisted the hot sulphurous gases perfectly for several months. I carefully examined several sections of it, which showed no trace of oxidation or deterioration of any kind on the inside, and it was pierced only where acid waters had come in contact with the outside. But for this ingenious device the whole works would have had to be shut down for several months.

Up to the year 1877 the chimney shown at Station 22 was the one used for carrying off all the furnace gases. The flue used up to the year 1874 was torn down, as it was too small for the increased production of the works, and was replaced by a larger one, better arranged for taking off the dust. In 1874 a large chamber was built next to this chimney, but after some years it was abandoned on account of the large amount of repairs which were required, and the chamber shown at Station 16 (Plate I.), and Fig. 10 (Plate II.), was then built. It was thought necessary, at the time it was constructed, to make an arrangement by which it could be cleaned very frequently, whenever the works should increase their production, and to have a cut-off, shown at *b* and *k*, so that the gases might be made to pass beside it into the main flue while it was being cleaned. It was

found, however, that the small quantity of dust collected made this unnecessary.

In the year 1877, the chimney at Station 47, and Fig. 13, was built, and connected with the flue leading to it on October 1st of that year. It was found necessary afterwards to increase the condensation surface, and on October 1st, 1880, the two buildings (X and Y, Plate I.), and Fig. 12, Plate II., containing condensing chambers, built beyond the chimney, were added to the flue. These buildings are 100 meters long. Each one of them consists of an upper and a lower chamber, with two divisions in each, separated by a flat ceiling which rests upon iron rails. The roof is inclined at an angle of 35° , and is made of iron rails riveted together with angle iron. Tiles are laid upon this and the joints covered with clay. The roofing which was put upon the northern section did not stand well, and, in consequence, in the latter part of the summer loam was laid over it, and this was covered with a second coating of beton. As sulphurous acid sometimes escaped from some of the other roofs, they were treated in the same way, and were then painted with tar. This kind of roofing does not appear to last very long, and is liable, on account of cracking, to require considerable repairs. When I visited the works, in September, 1882, the whole of the upper part of the chamber (Fig. 12), had been put out of use, as the roof was leaking gas so badly as to render the works liable to heavy fines. A large amount both of volume and surface was thus lost at that point, but the surface was almost immediately regained by the system described further on. The chimney is shown at Fig. 13. It is 42 meters in height above the socle, and its diameter is 2.47 meters in the lower part, and 1.80 meters above. As it was thought that this chimney might have a stronger draft than the proper working of the furnace would admit of, a movable damper was put in it (Fig. 13.) On the outside a quadrant was placed; an arrow attached to the axis moving over the quadrant shows exactly the angle of the damper in the interior of the chimney. When everything is working well, the angle is 45° . Before the addition of the chambers, X and Y, it was as low as 27° . The gas passes out of the main flue at *n*, by an elbow at Station 47, and enters the under part of the southern section of the condensing chamber building X (Fig. 12); it passes from that to the upper part of the same building, and then, at *p*, to the under part of the northerly building, Y, then, at *q*, into the southerly part, and finally at *r*, by an elbow, *r s*, enters a section of the main

flue, which has been walled off just beyond the elbow *n*, and from there goes directly to the chimney.

A number of experiments have been made to ascertain the temperature of the interior of the flues. It has been uniformly found that the temperature of the gases in the roof of the chambers was as shown in the table below :

At Station 15,	.	.	.	.	.	.	.	.	.	.	136° C.
" " 24,	.	.	.	.	.	.	.	.	.	.	119
" " 35, at <i>m</i> ,	.	.	.	.	.	.	.	.	.	.	108
At entrance of last chambers, X, Plate I., and Fig. 12, Plate II.,	.	.	.	.	.	.	.	.	.	.	89
Coming out from the " Y, " "	.	.	.	.	.	.	.	.	.	.	64

Although the sum of the sections of the two flues *ab*, *gh* is larger than that of the main flue at Station 16, they are not entirely filled with gas, and it is therefore not full, and consequently the temperature on the bottom is always some degrees lower than at the roof. The difference between these two temperatures is greater as the temperature of the gas is higher, and also as the height of the flue is greater. At Station 15, where the shaft furnace flue joins the main one, it was found to be 8° ; at the entrance to the chimney at Station 47, it was found to be 2°. The mean outside temperature varied during the days upon which these observations were taken, between 6° and 10°.

Table I, below, gives the dimensions, volume, and cost of the different parts of the flue, and the sections into which it has been found desirable, to divide it, for keeping the record of the action of the different parts of the flue. The cost has been given in marks. The value of one mark is \$0.238.

TABLE I.

NAMES OF THE DIFFERENT FLUES.	No. of the Section.	Description on the Plan.	The section is given on Table II.	Principal Divisions of the Canal.			Surface of the Side Bottom and Arch.		Cost, not including the Cost of the Ground.					
				Length.	Width.	Height to the Arch.	Total.	Sq. Mt.	For 1 sq. Meter of Inner Surface.		For the Running Meter.		For the Whole Length.	
									Mtr.	Mtr.	Mtr.	Sq. Mt.	M rks	Pfen-nigs.
1. From shaft furnace No. 3 to union with shaft furnace No. 2.	I.		Fig. 1	9.85	1.	1.10	43.72	4.43	11	90	52	82	520	27
2. From shaft furnace No. 2 to union with shaft furnace No. 3.			2	5.05	1.	1.50	27.80	5.50	11	90	65	51	330	82
3. From the union of shaft furnace Nos. 2 and 3 to the flue.....			3	18.	1.50	96.60	5.50	11	90	63	86	1149	54	
4. From shaft furnace No. 1 to the flue.....			4	8.	0.75	24.00	3.00	11	90	35	70	285	60	
5. From shaft furnace No. 4 to union with shaft furnace No. 3.	II.	a b	5	14.	1.	1.50	72.00	5.14	11	90	61	20	856	80
6. From shaft furnace No. 5 to the flue.....			6	9.	0.60	18.90	2.10	6	20	13	02	117	18	
7. Flue from junction with shaft furnace to the chamber.....			7	110.	1.50	655.05	5.95	17	30	102	93	11322	30	
8. Flue from the six southern roasting furnaces to main flue.....			8	20.	1.20	109.68	4.28	15	85	67	83	1356	60	
9. Flue from the northern double furnaces to end of schlich house.....	III.	e f	9	54.50	1.50	1.50	373.60	6.85	16	46	112	75	6144	87
10. Flue from the dressed-ore storage house up to the two northern double roasting furnaces.....	III.	f f	10	41.	1.20	1.20	224.84	4.28	15	85	67	83	2781	03
11. Flue parallel to the northern roasting furnaces.....	IV.	f g	11	66.	1.50	1.50	452.43	6.85	16	46	112	75	7441	50
12. Flue of the northern roasting furnaces.....	IV.	g h	12	397.	1.96	0.70	2555.57	6.43	15	78	101	62	40343	14
13. Flatter flues of the northern roasting furnaces.....	IV.	h i	13	66.	3.	1.50	594.00	9.00	9	76	87	84	5797	44
14. Chamber on the furnace hill.....	V.		14	16.30	9.30	{ 4.50 3.60	708.00	43.47	10	23	445	00	7253	46
15. Flue from chamber on the furnace hill to the upper part above old chimney.....	VI.	k l	15	160.60	1.80	1.80	1321.09	8.22	13	30	109	32	17556	79
16. Flue from above old chimney to edge of woods.....	VII.	l m	16	411.30	1.80	1.80	3383.35	8.22	13	30	109	32	44963	31
17. Flue from edge of woods to the close of the chamber.....	VIII.	m n	17	375.50	1.80	1.80	3088.86	8.22	13	30	109	32	41049	66
18. End of the flue.....	IX.	n o	18	20.50	1.80	1.20	144.03	7.02	10	44	73	38	1504	29
19. Under southerly chamber (I).....	IX.	{ X	19	100.	3.00	1.50	933.30	9.00	7	57	68	13	6813	00
20. Upper southerly chamber.....	X.		20	98.	3.17	2.50	1165.30	11.89	6	73	80	01	7840	98
21. Upper northerly chamber.....	XI.		21	98.	3.17	2.50	1165.30	11.89	6	73	80	01	7840	98
22. Under northerly chamber.....	XII.	p g	22	100.	3.00	1.50	933.30	9.00	7	57	68	13	6813	00
23. Connection from 1st to 2d chamber building.....	XIII.		23	8.50	3.00	1.50	76.50	9.00	9	76	87	84	746	64
24. Under southerly chamber (II).....	XIV.		24	100.	3.00	1.50	933.30	9.00	7	57	68	13	6813	00
25. Upper southerly chamber.....	XV.	Y	25	98.	3.17	2.50	1165.30	11.89	6	73	80	01	7840	98
26. Upper northerly chamber.....	XVI.		26	98.	3.17	2.50	1165.30	11.89	6	73	80	01	7840	98
27. Under northerly chamber.....	XVII.		27	100.	3.00	1.50	933.30	9.00	7	57	68	13	6813	00
28. Flue from under northerly chamber of No. 2 chamber building to the flue.....	XVII.	r s	28	22.	2.10	1.85	200.13	9.10	18	08	164	52	3619	44
29. The chamber joining the chimney to the northernmost chamber.....	XVII.	s t	29	10.38	1.80	1.80	85.37	8.22	16	33	134	23	1394	34
				2635.48			22650.62		11	27	96	81	255150	94

The cost of constructing the flue was large in certain parts of it, on account of the difficulty of carrying the building materials up to the high ground where the flue was built. On comparing the cost of each part of the flue, it appears that the flat portion of Section IV., Fig. 9, as well as the large condensing chamber buildings, X and Y, Fig. 12, were the cheapest. It must be noticed, however, that two of the flues have nothing to do with the saving of the flue dust. One of these is the one which goes to the old chimney at Station 22, and carries the gases from the stalls used for roasting the lead matte. These stalls are used only a short time during the year. The other is the one used for the ventilation of the shaft-furnace house.

Around each one of the five Pilz furnaces, one meter from its outside, and one and a half meters above the furnace-hearth, a sheet-iron cylinder two millimeters thick is placed. It is open below but closed above, and is joined to a pipe fifty centimeters in diameter. Each one of the pipes for the five furnaces passes through the charging-floor. They meet together outside of the building in a flue, which leads to the chimney L at Station 13, which chimney is 18 meters high and 43.5 meters above the charging-floor. This furnishes sufficient draft to carry off the fumes.

Table II. below, gives the results which have been obtained with the flues just described during seven campaigns. It gives also their length, interior dimensions, and cubical contents during the different periods of construction and change, and also the results which have been obtained by 100 meters in length, 100 square meters and 100 cubic meters respectively.

TABLE II.

	LENGTH OF THE CAMPAIGN.		The lead dust collected compared to 1000 Kilos of the lead contained in the ore.	Flues and Chambers.					The Lead Collected, compared to 1000 Kilos. of the Lead treated in the Roasting Furnace.				
				Length.	Section on the Ground.	Side and Arch Section.	Section.	Cubical Contents.					
	Date.	Time in Days.		Meter.	Sq. Mtr.	Sq. Mtr.	Sq. Mtr.	Cub. Mtr.	100 Mtr. Length.	100 sq. M Section on the ground.	100 sq. M Side and Arch Section.	100 sq. M Section.	100 cub. Meters. Cubical Contents.
1	May 1, '74, to Dec. '75, . . .	579	8.39	462.00	577.30	1808.17	2385.47	829.76	1.8160	1.4350	0.4640	0.3517	1.011
2	Jan. 1, '76, to April 15, '78, .	470	14.66	723.00	909.25	3238.62	4147.87	1565.86	2.0280	1.6120	0.4530	0.3534	0.9362
3	May 1, '77, to April 15, '78, .	350	26.71	1123.15	1685.07	6221.00	7906.06	3599.55	2.3780	1.5850	0.4290	0.3353	0.7420
4	May 1, '78, to May 21, '79, .	386	34.30	1308.47	2229.00	8481.68	10710.68	5336.93	2.6210	1.5390	0.4050	0.3202	0.6427
5 {	June 3, '79, to Dec. 3, '79 = 203 Jan. 1, '80, to Sep. 13, '80 = 257	460	42.56	1308.47	2229.00	8481.68	10710.68	5336.93	3.2530	1.9090	0.5020	0.3973	0.7975
6	Oct. 1, '80, to Aug. 11, '81, .	314	80.01	2635.48	5881.55	16769.07	22650.62	11025.59	3.0359	1.3604	0.4771	0.3532	0.7257
7	Aug. 28, '81, to Mar. 24, '82, .	200	84.80	2635.48	5881.55	16769.07	23791.14	11025.59	3.2176	1.4417	0.4734	0.3564	0.7691
8	April 16, '82, to Sept. 23, '82, .	160	. . .				34241.98						

In making the comparison of the material collected on every 100 square meters of wall surface and that of every 100 cubic meters of contents, the first four campaigns are particularly noticeable, as in these the relation of the square meter to the cubic meter, that is, to the mean section of the flue, has frequently changed. When the flues were first built they were made, as they usually are elsewhere, narrow. Those more recently constructed, which have served partly to replace defective ones and partly for the increased production of the works, are made much larger than they formerly were. The mean section of the entire flue has in this way become constantly larger, so that when the old flues were finally destroyed the large section was taken as the normal one for the new ones. In the first campaign the section of the flue was 1.79 square meters; in the second, 2.16 square meters; in the third, 3.21; and in the fourth, fifth, and sixth, 4.08 each. The only change in the seventh campaign was the insertion of 23,791.12 square meters of sheet-iron plates. Very little data can be given with certainty for the eighth campaign; several accidents occurred, which made it necessary to make the gases exit at the chimney at Station 22, so that for some time a large part of the flue was not in use. The cleaning and transportation of the flue-dust was made in very rainy weather, which made the weight of it uncertain. For these reasons this campaign has been left out of the question. Making a comparison of the quantity of lead collected per square meter of wall surface in the first four campaigns, the table shows that the quantities were nearly alike and varied regularly in very small quantities, while, on the contrary, the quantity collected per cubic meter during the enlargement of the flue was considerably less. From this the conclusion may be drawn that the material collected under such circumstances is proportional to the extent of wall surface, and that the cubical contents of the flue, including the chambers, has very little influence when the quantity of wall surface has undergone any change. These conclusions are fully sustained by the experiments formerly made with the two large condensing chambers X and Y, the increase of the cubical contents of the flue, owing to their addition, having been almost without influence.

The amount of dust collected on the bottom of the flue and of the condensing chambers was always much higher on the sides than in the middle, owing to the fact that after a certain quantity is caught on the walls, it falls to the bottom of the flue from its own weight and is heaped up there. In the last two campaigns a very much more favor-

able result was obtained than in the four previous ones, owing to the fact that much greater attention was paid to the regulation of the draft, by the damper in the chimney, which was kept closed so that the furnaces had only just the necessary draft. The material contained in the gases had thus much more time to settle on the sides, and that which had already settled either there or on the roof was not unnecessarily detached from it. The proportional quantity of dust collected upon a square meter of wall surface under similar circumstances is necessarily smaller the greater the section of the flue, so that by increasing the wall surface from 10,710 square meters as in the fifth campaign to 22,650 square meters as in the sixth, to 23,791.14 square meters as in the seventh, and to 34,291.98 square meters as in the eighth campaign the decrease of the material collected per square meter of surface is easily understood. The conclusion was therefore drawn, after the results of each period were known, that the wall surface of the flue might safely be enlarged, which was accordingly done. Before discussing the best way to make the final enlargement of the flue, it is well to carefully discuss the results obtained in the collection of the dust in the latest campaigns. From October 1st, 1880, to August 11th, 1881, which comprised the sixth campaign of the works, 14,605,261 kilograms of lead ore containing 6,247,605 kilograms of lead were treated in the works.* During this time, 927,483 kilograms of dust were collected, which contained 499,875 kilograms of lead. Per 1000 kilograms of lead contained in the ores treated, the dust contained $\frac{499,875 \times 1000}{6,247,605} = 80.01$ kilograms. The manner in which this dust settled in the whole flue system is shown in the table below.

* All the determinations of lead which are given in this article have been made in the wet way.

TABLE III.

Sixth Campaign, lasting from Oct. 1, 1880, to Aug. 11, 1881.

In the Division.		Dust.			
No. of Section.	By Square Meter of Ground, Side and Arch.	Quantity.	Lead contained.		Lead collected per 100 square meters of wall surface.
			Per 1000 Kilos.	Together.	
		Square Meter.	Kilos.	Kilos.	Kilos.
I.	283.02	68699	340.70	23405.97	8270.08
II.	655.05	43102	604.13	26039.34	3975.23
III.	708.12	53939	393.80	21241.56	2999.71
IV.	3602.00	92225	479.90	44285.78	1229.48
V.	708.70	71187	606.50	43174.92	6092.13
VI.	1321.09	65154	612.70	39919.85	3021.74
VII.	3383.35	157874	608.50	96066.33	2839.38
VIII.	3088.86	130950	556.70	72899.86	2360.09
IX.	1077.33	27319	610.20	16670.05	1547.35
X.	1165.30	39658	593.40	23533.06	2019.49
XI.	1165.30	32738	592.70	19403.81	1665.13
XII.	1009.80	26922	512.20	13789.45	1365.56
XIII.	933.30	19599	579.60	11359.58	1217.14
XIV.	1165.30	32405	507.80	16455.26	1412.10
XV.	1165.30	28688	473.60	13586.64	1165.93
XVI.	933.30	23713	467.10	11086.34	1187.86
XVII.	285.50	13311	524.70	6984.28	2446.33
	22650.62	927483	538.96	499875.08	2206.89

The great decrease of the lead in the dust is very noticeable. It is caused by the fact that before cleaning the flue the dust is usually set on fire. This is done in several sections at the same time, and is easily started with a single match. It is usually done with a handful of lighted shavings. It is burned to get rid of the soot, the very fine coal, and a part of the sulphur contained in the dust, so that the flues can be cleaned with less difficulty and danger to the workmen, and to change the very light dusty material into a compact agglomerated mass, which can easily be treated in the shaft furnace. This method of burning is successful if the dust has accumulated to a considerable thickness, when, as the coke and sulphur are burned out, the residue contains the most lead. That which is in thick layers, as it is generally the best burned, contains the highest percentage of lead. Whether the layer is thick or not is, however, for the purposes of this paper, a matter of no consequence, as all that it is necessary to know, is how much lead is collected per square meter of wall surface. The table below gives

flues, but that the difference should be so very great must have another cause. As the gases from Section II. and those coming from Section IV. come together in the chamber of Section V., it was to be expected that more dust would collect there. The amount collected, however, should, when the conditions remain the same, be less than the sum of that collected in Sections II and IV. According to the table, however, it is considerably larger. It is possible that this, as well as the unexpected quantity collected in Section I., is due to the fact that the walls in these two sections are entirely above ground, and are therefore easily cooled, while those of Sections II., III., and IV. are, for the most part, buried in the earth, and will, therefore, sooner or later acquire a temperature near to that of the gas. Apart from the condensing surfaces, the difference between the temperature of the gases and that of the walls of the flue should make a difference in the quantity of gaseous metals which can be condensed. The height of the temperature of the gases themselves has probably little or nothing to do with it. This, at least, seems to be the undoubted conclusion to be drawn from the results obtained in the Sections II. to XVI. When the different sections of the chambers are compared, as in Figs. 14 and 15, the greater quantity of material collected per hundred square meters of wall surface in the upper than in the under part strikes the eye at once. This can only be explained by the fact that the gases are more thoroughly cooled in the upper than in the lower part, the difference between the upper and the lower sections being that, with the exception of the partition floor, which is common to both, the side walls of the under part are made of thick masonry and are buried in the earth, while the upper one has very thin walls which are free.

Another argument to prove that cooling has an influence over the quantity precipitated is shown in the more rapid diminution in the upper section than in the lower. While the amount precipitated in the upper compartment varies from 2019 to 1165 kilos., that in the lower varies only from 1547 to 1187. This is undoubtedly caused by the fact that the gases in Section X. were at a temperature of 89° C., while those in Section XV. were at 64° . The difference between the highest and the lowest temperature in Section X. was, therefore, considerably greater than in Section XV., as was also the reduction of their individual temperatures. The reason that the precipitation per 100 square meters of surface in Section IX. is less by about 813 kilos. of lead than in the previous section, while the

precipitation in Section VIII. was only about 479 kilos. of lead less than in the one previous to it, is explained by the fact that Section VIII. lies with one side and the roof free to the air, and Section IX. is entirely buried. The calculation of how much has been collected per 100 square meters in Section XVII. is uncertain, because the dust found in the bottom of the chimney was weighed with it, and there is no means of ascertaining how far the quantity collected there was affected by the inner surface of the walls of the chimney.

Up to this time reference has only been made to the lead contained in the dust. The other components, however, are of interest, especially the silver, as its value is always of some importance. The last time the flue was cleaned, the dust, according to an assay of 1000 kilos., contained 51.86 grams of silver, so that the total amount of silver contained in the dust was 48 kilos. If, however, the quantity of silver which is contained in the lead obtained from the roasted and smelted dust is taken as a starting-point, the silver contained in 1000 kilos. would be 72.11 grams, or, altogether, 67 kilos., which quantity is, therefore, the normal from which all calculations must be made. With regard to the repartition of the silver in each section it is the greatest nearest the furnace, and then diminishes, at first rapidly, but after that very slowly. In the last campaign the amount of silver contained in the dust, according to an assay of 1000 kilos., was :

At Station	I.	.	.	.	.	.	.	.	.	150 grams.
"	II.	.	.	.	.	.	.	.	.	50 "
"	III.	Just behind the roasting-furnaces, .							.	75 "
"	IV.	.	.	.	.	.	.	.	.	60 "
"	V.	.	.	.	.	.	.	.	.	45 "

From this point the silver diminishes gradually till at the end of the flue it is only 30 grams.

It appears very clear from these assays that in the beginning the dust contains a considerable quantity of particles mechanically carried off, which, on account of their weight, can only be transported a certain distance. When the draft is stronger they will be carried further, and its influence will be shown in the increase of these small particles of ore. This explains why it is that in former years, when there was no damper in the chimney, there was nearly half as much more silver in the flue-dust as now. From the fact that the ratio of lead to silver in the flue-dust is different from that in the ore, it is certain that in the discussion of this whole question the condensation of the volatilized material is by far the most essential consideration.

The dust contains between three and five per cent. of zinc. In general it can be said that it is greater in the beginning than at the end of the flue. The difference, however, is not very great. The antimony contained is between 0.21 per cent. and 0.40 per cent. It decreases very gradually in the length of the flue. The dust which is deposited on the bottom of the flue often contains 10 per cent. more lead than that which is deposited on the arch. This observation has been confirmed every time the flue has been cleaned. The analyses of two samples of dust which was deposited by Station 46, more than 1500 meters from the beginning of the flue, is given below :

ANALYSES.

	I.	II.
Lead, ...	60.48 per cent.	67.04 per cent.
Zinc, ...	3.17 “ “	4.22 “ “
Silver, ...	0.003 “ “	0.003 “ “
Sulphuric acid.	14.78 “ “	14.07 “ “
Sulphur, ...	6.22 “ “	5.42 “ “
Oxide of iron, }	2.12 “ “	1.00 “ “
Alumina, }		
Carbon, ...	8.00 “ “	5.80 “ “
Antimony, ...	0.42 “ “	0.31 “ “
Arsenic.	0.24 “ “	0.16 “ “
Copper, ...	trace.	trace.
Lime, ...	1.15 “ “	0.61 “ “
Total, ...	96.583 “ “	98.633 “ “

Assay No. I was taken from the arch and No. II from the floor directly under it. The difference between these two will not be apparent when large masses are considered, for the dust increases in depth on the floor, because that which collects on the roof after a time gets heavy and falls to the ground on the top of that collected there, so that the results obtained by the analysis of a sample taken from a large quantity will be a mean of the two, and will not represent either the one or the other.

From these facts it is plain that the most important consideration is not that of collecting the particles of ore which are mechanically carried off, but of condensing and collecting those which have been volatilized and sublimed. Two separate means can be used for condensation, and these are the proper application of wall surface, and some method of cooling that surface. There is a limit to the possible cooling of the wall surface, and in any case this method can only be useful up to the point where the gases are reduced approxi-

matively to the temperature of the outer air; beyond this point artificial means of producing the draft would have to be used. How far the flue can be cooled will depend on the material used for the construction of the walls, and whether the flue itself is more or less buried in the ground.

The limit of methods of construction lies between sheet-iron flues suspended in the air or laid on the surface of the ground and masonry flues buried entirely in the earth. The lowest point to which the gases can be cooled will be that which will give the necessary draft for the proper conduct of the furnace. The chimney must, therefore, be built either upon a high elevation or must itself be sufficiently high to produce the draft, or the gases at the foot of the chimney must have their velocity increased, either by bringing the gases at that point up to the requisite temperature, or by causing the air to move by power. In the works at Ems little can be gained by the further cooling of the gases, as these at the foot of the chimney at Station 47 on the top of the hill have only a temperature of 64° C., so that to increase the quantity of dust collected more surface must be provided. Since the intercalation of the last two chambers, which with their necessary additions have a surface of 8815 square meters, it has been found necessary to open the damper of the chimney to 45° . Formerly it could only be opened with safety to 27° . There is little or nothing to be done further to increase the draft except to open the damper entirely, or to increase the height of the chimney. This must be done when a second condensing-chamber building like those at X and Y, is constructed as it must be. The cost of this construction would be 64,486.29 marks; according to the last experiments that were made, this sum would be repaid at the latest inside of three years. As, however, all that is necessary now is to increase the wall surface, this can be done more quickly and cheaply by placing sheet-iron plates in the flues already constructed. This system was tried in Section XVI. from August 28th to December 24th, 1881. Four rows of sheet iron, No. 22, 100 meters long and one wide were hung in the flue. Taken together they represented 800 square meters surface; the collective wall surface of this division was, therefore, increased from 933 to 1733 square meters. The quantity of lead contained in the ore and in the dust at this time was 3,028,565 kilograms. In the previous campaign of the 6,748,816 kilograms of lead in the ore and dust which was treated, there were collected in Section XVI. 23,713 kilograms of dust. It was, therefore, calculated that with the increased wall surface

from this arrangement of thin plates, 19,766 kilos. would be collected in this. The amount actually collected was 18,800 kilos. which was somewhat higher in lead than that collected in the previous experiment. The results of these experiments were so satisfactory that the number of plates was increased to six, as shown in Fig. 16. The quantity thus collected was so very large that in some of the sections of the main flue, notably in Figs. 11, 12, and 17, vertical plates 10 millimeters apart were introduced. As this method of construction costs only about one-tenth as much as the same amount of wall surface made with masonry, and allows of regaining more flue dust than the construction of long flues and condensing chambers without it, a patent for the improvement has been taken out in the name of the Ems Lead and Silver Works,* which has proved not only useful for metallurgical but also for chemical and other manufacturing works where metals are likely to be volatilized. It is also probable that its use will be found advantageous in the manufacture of zinc white, the treatment of ores of mercury and other volatile substances, where the main object of the treatment is the condensation of the volatilized metals.

After the first trial the hanging plates were introduced into Sections VI., VII., and VIII., a section of which is shown at Fig. 11. They were then introduced on a much larger scale in Sections V., VI., VII., VIII., and IX., as shown in Figs. 16 and 17.

The method of hanging-in the sheet-iron consists in placing a rectangular bar of iron, which has been pierced with the requisite number of holes, on its edge, in the spring of the arch, if the arched form of flue is used, or at the proper height in the rectangular ones. This bar is twisted flat at its ends so as to enter the wall about 3 cm. Iron pins, 10 cm. between centres, are driven into the holes, projecting 3 to 4 cm. on both sides. A piece of iron, D, Fig. 17, bent to form a hook, is riveted upon the ends of each sheet, so that it simply drops on to the pins, and hangs at each end supported in a vertical position. So arranged, the sheets can be put up or taken down with the least possible trouble. To simplify the construction, a punching machine is used which pierces two holes at once in the sheet-iron at the proper distance from the edge. The iron which forms the hook L, Fig. 17, is punched in the same way. The riveting is done with two or three blows of the hammer. When the sheets are hung upon the pins they fill up the flue, and have between them in

* Jan. 13th, 1881, Germany, No. 17,513.—March 12th, 1882, Hungary, No. 8454.—October 20th, 1881, England, No. 4590.—April 3d, 1882, Spain, No. 2232.—March 12th, 1882, Austria, No. 3723.—April 24, 1883, United States, No. 276,386.

the direction of the length of the flue only the thickness of the iron bars on which they rest. These sheets do not make any perceptible reduction of the total volume of the flue, but they increase the condensation-surface enormously.

Fig. 16 shows the arrangement of Fig. 11 when only six sheets were used; Fig. 17, the arrangement of the same flue when 17 are used. A vacant space is left, as C E C L in Fig. 17, to show the method of hanging-in the sheets on the iron bars L, as well as the method of supporting the partitions on the bottom of the flue. In order not to impede the draft these plates must be placed parallel to its direction, and be as thin as possible. It will also be necessary to place them as nearly vertical as possible so that when the dust condenses upon them, after it has attained a certain thickness, it will fall down upon the floor of the flue and remain there. In order to bring the quantity of dust which settles up to a maximum, the material which has once been condensed and brought to rest, should remain, as far as possible, where it was arrested, or if allowed to move should fall vertically on to the floor, and remain there, so that it would no longer be possible for it to be caught up again by the draft and be carried up the chimney. The simplest and cheapest means of effecting this, is to make partitions, about 50 cm. high and nearly touching the vertical sheets, across the bottom of the flue, as is shown at E, Figs. 16 and 17. Every five or six meters, or less, partitions are made at right angles to the direction of the draught. In the first experiments they were made of stone, laid up dry, as shown at E, Fig. 16. It has been found best, in the more recent constructions, to make them of sheet-iron, as is shown at E, Fig. 17. The sheet-iron is supported in wrought or cast-iron feet C, to which it is attached by bolts. It is easily set one side when the flue is cleaned, or can be quickly removed from the supports if it is for any reason necessary to do so. This kind of construction has the advantage of not only being easily removed and replaced, and of being quickly repaired, but it is never in the way. The dust collected is purer, because there is no chance of having small particles of broken stone mixed with it. This method of using plates for increasing the condensing surface costs very little, as any kind of sheet-iron can be used. The cost of putting in is only 21 pfennigs. By the ordinary construction one meter of the length of the flue gives only 8.22 square meters of surface; altered in this way, the same length gives, with six plates, 65 square meters of surface, and with

seventeen, 184 square meters, while its volume is lessened only a very little.

In all parts of the flue where these sheet-iron plates have been placed, enormous quantities of dust have been found every time the flue has been cleaned, the quantity being greater as the surface was larger. As no such quantities have been found before, and as the increase in quantity is directly in the ratio of the increase of the surface, there is every reason to believe that it will prove effectual up to a limit which has not yet been ascertained. The quantity of dust collected, especially in the last section of the flue, was very large. Usually, but very small quantities can with certainty be counted on in that position. It seems probable that by the use of a suitable construction, a still larger part of the dust can be collected, and most of that which is now lost saved, thus diminishing the expenses and increasing the receipts of the works very considerably.

With regard to the number of sheets to be introduced in each section of the flue to produce a maximum effect, it may be said the more the better, provided they do not interfere with the draft. It has been found best to use very thin sheets, and to concentrate them, as far as possible, in a small portion of the flue, rather than to scatter them throughout it, or over a very large part of it, as the cost of construction will for this reason be less. Whether more than seventeen or eighteen sheets can be used in a flue of the size of Sections VI., VII., VIII., and XVII., or whether, in a larger flue, it will ever be found advantageous to hang them closer than 0.01 meter apart remains to be seen. Up to the end of the ninth campaign they were hung 0.01 m. apart. So much dust was then collected in Section VI. by this method that the flues became choked and the furnace had to go out of blast. The plates can only be hung so close together at the end of the flue without endangering the length of the campaign, unless auxiliary flues are provided, as has been suggested, so that the sections may be cleaned whenever desirable by turning the gases into the auxiliary flue, and when that is full, back again, without stopping the works. No general rule can be given either for the number of plates nor for their relation to the width of the flue, for the quantity of gases passing through it, or the quantity of sublimed material likely to be contained in the gases. They not only differ in the different works, but they are often different in individual parts of the same works. The use of sheets thinner than 0.675 mm. would give more surface for the same volume, but they would have to be supported differently, as they would be likely to be moved

from side to side by the blast. If they were hung from the top, there would be danger of their meeting at the bottom, and thus obstructing the draft. To support them in more than one place would naturally increase the difficulty of using them as well as the cost. The introduction of three or four more in the same space would largely increase the surface, but could not be done advantageously if it increased the difficulty of manipulation, or the cost at the same time. More plates would then have to be used in the length of the flue. The cause of failure, if any, in the system would be the increase of friction-surface, and this limit would have to be found in every case. Whether it will be wise to increase the section of the flue in order to introduce more plates can only be ascertained by experiment. When careful records of the action of each shape of flue, where the plates are used, have been made, the ledger account will soon show which form of flue it is most economical to adopt.

The material used for the plates may be different according to the temperature which obtains in that part of the flue where they are to be used. Thin sheet-iron seems to be the best, which need not even be new. The worn-out iron sieves of the jigs from the dressing-works can be used, and where the temperature is very low, as in the last section of the flue, next the chimney, on the hill, pasteboard can be used. Combustible material cannot, of course, be used where the flue is to be fired. It would be best, however, to make experiments in each case as to what material will be most suitable.

Whether these plates can be best hung up or fixed permanently, as well as the best way of carrying out the rest of the system, must be determined in each special case. It will generally be found best to have them easily removable, to facilitate the firing of the dust (which is peculiar to the works at Ems), as well as to facilitate the cleaning of the flue.

In England a patent was taken out in the year 1880 for plates which are put in horizontally. The object of this invention is to collect the dust by making the draft as slow as possible and causing the particles arrested to fall the shortest possible distance. To diminish the velocity of the gas, it is passed from the main flue into very large condensing chambers, built at the side of the main flue and divided by parallel walls into a large number of flues, in which iron plates are placed horizontally and close together the whole width of the flue, so as to make the fall of each particle as small as possible. There is no doubt that so far as the collection of the dust is concerned, this system will do it rapidly, but the system itself is

both defective and expensive. As the dust is accumulated in horizontal layers, the volume of the flue is rapidly diminished, and as there is no provision made for arresting the dust where it falls, the amount of surface must always be a maximum. It will take a long time for such large condensing chambers to cool down so that the men can enter them, so that much time will be lost before they can be cleaned. The danger to the men by bringing them in contact with this impalpable dust, which is set in motion every time one of these layers is removed, while cleaning the flue, will effectually prevent the general introduction of this method.

The seventh campaign lasted 200 days, the details of which are given in table IV below.

TABLE IV.

Seventh Campaign, lasting from Aug. 28th, 1881, to March 24th, 1882.

There was collected from the 28th of August, 1881, to 24th of March, 1882					
In Section.		Quantity of Dust.			Quantity of Lead per 100 Square Meters of Wall Surface.
No. of Section.	Square Meter of Ground, Side, Wall, and Arch Surface.	Weight.	Lead Contained.		
	Square Meter.	Kilos.	Per 1000. Kilos.	Total Lead. Kilos.	Kilos.
I.	283.02	75449	401.163	30267.38	10694.43
II.	655.05	8471	609.300	5161.38	787.93
III.	708.12	12392	433.552	5335.40	743.46
IV.	3602.00	75265	443.316	33336.22	926.32
V.	1049.20	30171	619.047	18677.26	1780.14
VI.	1321.09	35257	628.199	22148.41	1676.52
VII.	3383.35	110576	626.400	69464.81	2047.22
VIII.	3088.86	74050	624.000	46207.20	1495.93
IX.	1077.33	27150	669.106	18166.22	1686.23
X.	1165.30	25150	646.300	16254.44	1394.87
XI.	1165.30	24600	638.300	15702.18	1347.48
XII.	1009.80	22500	615.330	13844.92	1371.05
XIII.	933.30	21950	623.396	13683.54	1466.15
XIV.	1165.30	20950	547.900	11478.50	985.02
XV.	1165.30	26800	577.600	15479.68	1328.38
XVI.	1733.30	33100	595.979	19726.91	1138.11
XVII.	285.50	8900	590.907	5259.07	1842.06
	23791.12	632731	568.999	360028.52	1513.27

The value of the 632,731 kilos of dust is 88,542 marks. If the seventh campaign had lasted 350 instead of 200 days, the corresponding value would have been 1,107,296 kilos of dust, worth 155,019 marks.

The sixth campaign lasted 314 days. During this time the ore treated contained 6,247,605 kilos. of lead, the details of which are given in Table III., page 15. The seventh campaign lasted only 200 days, and the ore treated contained 4,245,303.21 kilos. of lead. In order to make the comparison between the two the amounts given for the seventh campaign will have to be increased in the ratio of 4,245,303.21 : 6,247,605. This has been done in table V., below :

TABLE V.

The Seventh Campaign increased for the purpose of comparison with the Sixth Campaign.

There was collected from the 28th of August, 1881, to 24th of March, 1882					Quantity of Lead per 100 Square Meters of Wall Surface.
In Section.		Quantity of Dust.			
No. of Section.	Square Meter of Ground, Side, Wall, and Arch Surface.	Weight.	Lead Contained.		
	Square Meter.	Kilos.	Per 1000. Kilos.	Total Lead. Kilos.	Kilos.
I.	283.02	111030.75	401.163	44541.43	15737.92
II.	655.05	12465.92	609.300	7595.48	1159.52
III.	708.12	18236.06	433.552	7906.28	1094.04
IV.	3602.00	110759.97	443.316	49101.67	1363.17
V.	1049.20	44399.64	619.047	27485.46	2619.65
VI.	1321.09	51884.20	628.199	32593.60	2467.17
VII.	3383.35	162723.64	626.400	101930.09	3012.69
VIII.	3088.86	108971.98	624.000	67998.52	2201.41
IX.	1077.33	39953.94	669.106	26733.42	2481.46
X.	1165.30	37010.74	646.300	23920.04	2052.69
XI.	1165.30	36201.36	638.300	23107.33	1982.95
XII.	1009.80	33111.00	615.330	20374.19	2017.64
XIII.	933.30	32301.62	623.396	20136.70	2157.59
XIV.	1165.30	30830.02	547.900	16891.77	1449.56
XV.	1165.30	39438.88	577.600	22779.90	1954.84
XVI.	1733.30	48709.96	595.979	29030.11	1674.84
XVII.	285.50	13097.24	590.907	7739.25	2710.78
	23791.12	931126.92	568.999	529865.24	2226.93

It is to be noticed that in Section V., which is the condensing chamber at Station 15, shown at Fig. 10, the quantity of wall surface has been increased from 708.10 square meters to 1049.20 square meters, and that of Section XVI., which is the lower northerly part of the condensing chamber Y, at the top of the hill, Fig. 12, from 933.30 to 1733.30 square meters. Section V. is very near the furnaces. Section XVI. is at the foot of the chimney.

Table V. shows that there has been a very large increase in the

quantity of dust collected, except in Sections V., VI., VIII., X., and XIV., where the quantities are in round numbers 26,000, 13,000, 3000, 2500 kilos. less. The total quantity collected is, however, greater than in the sixth campaign, and almost in direct proportion to the increase of wall surface. But in every case where there is a diminution, except in Section XIV., there is an increase in the quantity of lead per 1000 kilograms. The quantity of lead per square meter of wall surface is less in Sections V., VI., and VIII., and slightly more in Sections X. and XIV. The total quantity is, however, enough more to justify close attention.

It would naturally have been thought best, as soon as the practicability of this method of using iron plates had been proved, to have hung the whole flue full of them, but as no sufficient data had been collected as to how far the draft would be affected by it, it was done very gradually. Before the seventh campaign, in August, 1881, 1140 square meters were put in. In March, 1882, before the eighth campaign, 10,450.86; and after the eighth campaign, in September, 1882, 13,055.35 more, so that up to this time there were 24,471.60 square meters of sheet-iron plates hung in the flue. An accident, which happened in the summer of 1882, made it necessary to do away with the upper part of the condensing-chamber building, which includes Sections X., XI., XIV., and XV., Figs. 14 and 15, as the roof was no longer tight. The flue itself had then 18,060.01 square meters of wall surface; this, with the 24,471.60 square meters of sheets, made 42,531.61 square meters of available condensing surface. The sheet-iron plates introduced cost 18,108.98 marks. If this amount of surface had been introduced by means of a masonry canal, such as is shown in Fig. 9, the square meter of which costs at least 11.71 marks, it would have amounted to 286,562.44 marks. There was thus saved by the use of the iron plates a sum of 268,483.46 marks.

It was a matter of some interest to ascertain whether the draft had not been diminished by the enormous friction surface which has been added in the flue by the very large amount of surface introduced into it. As the entire flue during the three weeks that the works were obliged to stop for these repairs, was very much cooled, it was found that at the time the works were put into blast again, there was such a very weak draft that it was necessary to put a fire at the bottom of the chimney on the top of the hill. After three days' use of it the draft was sufficiently strong to make it no longer necessary. The damper in the chimney is now not entirely open. Little by little it will be brought back to its former angle.

With regard to the temperature in the flues, the gases escaping from the chimney in the normal working of the establishment have a temperature of between 60° and 70° . With regard to the quantity of lead contained in the dust, setting it on fire undoubtedly diminishes the quantity more or less, but that upon the arch, which afterwards falls to the ground, does not contain as much as that which collects on the bottom of itself. Taking the sample for the assay is on this account very difficult, and mistakes are very apt to be made, when the fact of the dust collecting in layers of variable richness is not taken into account. The assays taken at the end of the seventh campaign were in any case more nearly correct than those taken at the end of the sixth.

The sheet-iron plates which have been hung have lasted extremely well. Not one of them has as yet been damaged, and it seems more than likely that they will last at least five years. The only danger appears to be from dampness which would cause them to rust, and this can only be avoided by confining the plates in the flue where they are hung to such a distance from the furnaces that it is certain that all the dampness will have previously been condensed out of the gases, and by properly draining the surface so that no moisture can collect in it from the outside. By this system it is possible to collect the whole of the dust in a small part of the flue near the works, and thus save a large amount of transportation of the material collected, while at the same time diminishing by so much the loss consequent on carrying it. This loss by transportation will, of course, be reduced to a minimum when the dust is agglomerated.

Cleaning the flue necessitates, at certain intervals, a stoppage of the works, so that only those places are frequently cleaned in which the sheet-iron hangs, while the flue itself is cleaned at longer intervals. In those places where a stoppage of the works is impossible, two flues filled with sheet-iron plates can be built side by side in the most convenient situation, so that either one may be connected or cut off entirely from the main flue, according as they have been cleaned or are to be cleaned, without stopping or even hindering the work of the furnace at all.

In order to ascertain how far this system of enlargement of the flues can be carried without danger, and how far the wall surface can be increased, and what is the limit at which it would pay, a table of the results of the sixth and seventh campaign at Ems is given below in Tables VI. and VII., taking as a basis Table III., page 15.

The sixth campaign was 314 days. In order to see the results more clearly the calculation has been made as if the campaign had been a year of 350 working days and 15 days of rest for cleaning out the flues. The quantities given in Table III will, therefore, be found altered in the ratio of 314 to 350. The value to the works of 100 kilograms of the dust collected is calculated on the supposition that the price of 100 kilograms of lead is 29 marks, and that the loss by the treatment is five per cent., and that the cost of treatment including transportation is 2.4 marks per 100 kilograms. The value of the silver is included in the calculation.

TABLE VI.
Sixth Campaign, reduced to 350 days.

There was Collected							Value of the Dust per 100 sq. Meters of Wall Surface.	
In the Section		Dust.						
Number.	By Square Meter of Ground, Side and Arch.	Quantity.	Value.					
			Per 100 Kilos.		Together.			
	Sq. Meters.	Kilos.	Marks.	Pfen'gs.	Marks.	Pfen'gs.	Marks.	Pfen'gs.
VI.	1321.09	726240	15	24	11067	90	837	84
VII.	3383.35	175974	15	13	26624	87	786	95
VIII.	3088.86	145963	13	65	19923	95	645	04
IX.	1077.33	30451	15	17	4619	42	428	76
X.	1165.30	44205	14	73	6511	40	558	74
XI.	1165.30	36491	14	71	5367	83	460	65
XII.	1009.80	30009	12	46	3739	12	370	27
XIII.	933.30	21846	14	26	3115	24	333	76
XIV.	1165.30	36120	12	26	4428	31	379	99
XV.	1165.30	31977	11	35	3629	39	311	42
XVI.	933.30	26432	11	02	2912	81	312	12
	16408.23	652092	14	10	91940	24	560	34

In order to compare the results of the seventh campaign with those of the sixth, the same calculation has been made which is given in Table VII., below :

TABLE VII.

Seventh Campaign, reduced to 350 days.

There was Collected								Value of the Dust per 100 sq're meters of Wall Surface.	
In Section		Dust Collected.							
Number.	Per square meter of Ground Wall and Arch Sur- face.	Weight.	Value.						
			Per 100 Ks		Total.				
	Square Meters.	Kilos.	Marks.	Pfeng's	Marks.	Pfng.	Marks.	Pfeng's	
VI.	1321.09	57830.13	15	90	9194	99	696	15	
VII.	3383.35	181371.77	15	76	28584	19	844	85	
VIII.	3088.86	121460.17	15	69	19057	10	616	96	
IX.	1077.33	44532.66	16	93	7539	38	699	82	
X.	1165.30	41252.17	16	37	6752	98	579	50	
XI.	1165.30	40350.04	16	00	6456	00	554	02	
XII.	1009.80	36905.52	15	40	5683	45	562	83	
XIII.	933.30	36003.39	15	64	5630	93	603	34	
XIV.	1165.30	34363.14	13	59	4669	95	400	75	
XV.	1165.30	43958.58	14	41	6334	43	543	60	
XVI.	1733.30	54292.12	14	95	8116	67	468	28	
	17208.23	692319.69	15	60	108020	08	627	72	

In these tables Sections I. to V., both because they have given exceptionally favorable results and because the gases are only collected in the main flue at Section V., have been omitted. Section XVII., as designated after Table VII., because of the unknown effect of the wall surface of the chimney, is also left out.

To make these results of the sixth and seventh campaigns apparent to the eye they have been graphically represented on Plate III. The abscissas indicate the number of square meters of wall surface contained in every section; the ordinates represent the total value of the dust collected in each section and also the value per 100 square meters of wall surface. Each section is thus represented by a rectangle which gives a graphic representation of the total quantity of wall surface contained in each, and the value of the material collected. These are printed on the middle line of the rectangle representing each section. In each rectangle there are two figures giving the value of the dust collected, the upper one being for the sixth and the lower for the seventh campaign. The lines of the sixth campaign are represented in full while those of the seventh are represented as dotted. The ends of the middle ordinates are joined, making a zigzag line which is quite different for each one of the sections in the two campaigns; a curve representing these lines has been given, showing

the value of the dust collected for both the sixth and seventh campaign.

During the seventh campaign no change in the quantity of wall surface was made except in Section 16 where the wall surface was increased from 933 square meters to 1733 square meters. It is very remarkable that while between these two campaigns no change in the quantity of wall surface has been made except in Section XVI, all the weights and values have been altered by this single change; and that while the flue has been made very much shorter by the cutting out of the condensation-chambers X and Y, the wall surface has been so much increased by the addition of sheet-iron plates that with the exception of Sections VI and VIII the value has in every section been increased, while the total value has been very largely increased, which is shown by the curve representing Section XVI in the seventh campaign being very much higher than that of Section XVI in the sixth campaign, making the total value of the dust collected in this Section more than three times what it was in the former campaign while the surface has not been quite doubled. This shows beyond doubt that the quantity of material collected is proportional to the extent of wall surface, and that the cubical contents of the flue itself is of importance only as it allows of a maximum amount of surface in the shape of plates being introduced within it. It is also to be remarked that while the curve in the seventh campaign is much flatter it commenced in Section VI with less value, and there seems, therefore, no doubt whatever that this method which is not only cheap, so far as the installation is concerned, is also by far the most effective of any which has yet been devised for the collection of flue-dust, and notably for the condensation of the volatilized material. It is to be noticed that there are three separate causes which will make the curve flatter. The first of these is the decrease in value, owing to the complete separation of the particles mechanically carried off; the second is the decrease in value, owing to the reduction in temperature; and third, the decrease in the value of the gases, owing to the separation of the metallic particles held in suspension.

As is shown by the results, the first cause, that is the separation of the particles carried off mechanically, acts within a very short distance from the furnace, so that by the proper construction of the condensing plates, nearly the whole of the ore particles will be separated from the gases, not far from the furnaces themselves. There will remain then in the gases only the volatilized metals.

Some of the causes of the difficulty of the separation of them from the gases have been already discussed. It appears, however, that the curve might easily become a straight line if it were possible by the introduction of an infinite quantity of surface to condense the whole of the dust. It would seem from the discussion of these two curves that the influence of the reduction of temperature was not as great as it appeared to have been from the experiments made in the sixth campaign. It will, however, probably be found expedient on account of repairs to still further disengage the sides of the flue, both for convenience of repairs and convenience of access.

It appears from Table I., page 10, that the cost of the construction of a square meter of wall surface in the flat flue of Section 4, exclusive of the cost of the ground was 9.976 marks. This calculation is made on the supposition that the cost of the ground for the square meter of wall surface was 0.44 marks; one square meter will, therefore, cost 10.20 marks, and 100 square meters will cost 1020 marks. In all these observations the condensing chambers X and Y, since they have cost so much for repairs, have been left out of the consideration altogether as defective, are not taken into the calculation.

The square meter of wall surface made of new sheet iron, No. 22, including the cost of erection, will not cost more than 0.75 marks. One hundred square meters would, therefore, cost 75 marks. In making up the cost of these two methods of getting surface as is shown upon Plate III., 10 per cent. of the cost of construction has been charged for the sinking fund of the masonry walls, while for the sheet-iron surface, 20 per cent. which is a very large charge, is made. The yearly charge, then, for the sinking fund for the 100 square meters of masonry surface, would be 102 marks, while for the surface obtained by hanging in the sheet-iron plates it would only be 15 marks. The difference between the two is shown very decidedly in the lines representing the cost, Plate III. From the experiments which have already been made since the introduction of these sheet-iron plates in the flues, 20 per cent. seems to be a very exorbitant charge, although made very high purposely, in order to make the most disadvantageous comparison between the two systems. No perceptible alteration or wear has been shown after a use of five years, so that if less than 20 per cent. is charged, the line would go still lower than it now does, and it would seem to be the natural conclusion that the cheapest method would be to build short, large flues in which the maximum of wall surface was obtained by the intercalation of these plates. All the experiments made up to the present time

fully justify the conclusion, that not only is this the most economical method of saving a quantity of material which has hitherto gone to profit and loss, because it was supposed to be impossible to save it, but that it is also possible to reduce very largely the cost of the works by increasing the wall surface indefinitely at a very cheap rate. The most remarkable fact relating to these experiments is this, that by almost doubling the wall surface in the last section of the flue which is furthest removed from the works, where there was no probability that any material mechanically carried off by the gas would be still retained suspended in it, there is such a large amount of value obtained from the dust. This can only be attributed to the fact that the metallic material which is volatilized, and which is collected with such great difficulty, has been carried to that point and condensed there, and that without this increase of wall surface this large amount would have gone up the chimney and been entirely lost. It seems, therefore, that not only in all works where the flue-dust contains value should especial attention be given to collecting it, but that the quantity of metal which is actually volatilized, merits special attention.

When the values which represent the different sinking funds for the year are transferred to Plate III., and compared with the curve which shows the value of the dust collected in the different divisions of the flue, and these data are also compared with the very great value of the flue-dust collected, it is a matter of surprise that the collection of flue-dust in metallurgical works does not appear to have attracted more special interest than it has done, if only on account of its pecuniary importance.







